RESEARCH DEPARTMENT

Field-store standards conversion: a comparison of amplitude and frequency modulation systems

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SUMMARY

Proposals have been made for field-store television standards converters using ultrasonic delays as storage devices. Previous experiments have shown that variations of gain of the amplifiers associated with these ultrasonic delays must be very small if impairment of the converted picture is to be avoided. The use of frequency modulation for transmission of the signals through the ultrasonic delays would give a very high degree of gain stability and would thus offer a substantial advantage over amplitude modulation. The object of the experiments described in this report was therefore to compare the picture impairment occurring due to spurious signals when frequency and amplitude modulated signals are transmitted through the ultrasonic delays of a field-store converter.

1. INTRODUCTION

A number of proposals for field-store standards conversion have been made, all of which are based on ultrasonic delays using fused quartz as the storage medium.[1,2,3] In the proposal which appears to be most suitable for development, successive sequences of scanning lines of the input television standard are delayed by integral multiples of T.* Thus a sequence of input scanning lines is delayed by nT where n is an integer and the next sequence by (n + 1)T or (n - 1)T depending on the direction of the conversion. In the case of conversion from the American 525-line, 60-field standard to the British 625-line, 50-field standard the various values of delay, each equal to an integral multiple of T, are achieved by switching the signal among a set of eight delays whose durations are all binary multiples of T (i.e., 2^rT where r is an integer) up to 128T. The signal may be transmitted either through a particular delay or through a by-pass route associated with that delay and there exists for each delay and by-pass route a well-defined switching sequence dependent on the phase relationship between the input and output synchronising pulses. For example, signals corresponding to sequences of five or six lines are alternately transmitted through the delay of duration T and its associated by-pass route. In general, successive sequences of scanning lines are routed through different combinations of the ultrasonic delays and, if the performances of the delays differ, picture impairment of a regular and repeated form will occur.

In a previous report,[4] experiments are described which were carried out to determine the variations in performance of the ultrasonic delays which could be permitted without unacceptable picture impairment. The results of these experiments show that the differences between the gains of the different combination of delays must be less than ± 0·05 dB. Such a tolerence on gain stability would be extremely difficult to achieve if signals were transmitted through the delays by means of amplitude modulation (a.m.) but quite easy to achieve if frequency modulation (f.m.) were used. On the other hand, the use of f.m. raises a number of problems due to the relatively low bandwidth of ultrasonic delays; these problems are discussed in a separate report.[5]

Experience has shown that it is difficult to obtain fused-quartz ultrasonic delays having spurious signals at sufficiently low levels. It is therefore essential to know whether the picture impairment due to these spurious signals is greater or less for an f.m. system than for an a.m. system. The experiments described in this report were carried out to assess the extent to which spurious signals can be tolerated with both types of modulation.

2. THE EFFECT OF SPURIOUS SIGNALS IN THE CONVERSION SYSTEM

In a field-store converter, the signal to be delayed modulates a radio-frequency (r.f.) carrier and the modulated carrier is propagated, as an acoustic wave, in the fused quartz of each ultrasonic delay. Each complete delay unit consists of an input amplifier, input transducer, quartz block, output transducer and output amplifier. Spurious signals generated in the ultrasonic delays consist of a coherent repetition of the main signal separated from it in time and arise by transmission between the input and output transducers along some path in the quartz block different from the one which was intended by the designer.[6] In short delays (less than 0·5 ms) the only significant spurious signal is known as the "third-time round"[6] signal and results from a reflection of the signal at the output and input transducers; these spurious signals are therefore delayed relative to the wanted signal by twice the delay suffered by the wanted signal. In long delays (greater than 1 ms) other types of spurious signal arise (mainly from reflections from the top and bottom faces of the quartz block); these may be delayed by varying amounts and may arrive either earlier or later than the wanted signal.

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* T is an important parameter[1] which in the case of one method of conversion between 525-line 60-field and 625-line 50-field standards has the value T = 66·7 μs.

Previous work[7] in connection with other problems had indicated that the level of spurious signals should not exceed -38 dB relative to the wanted signal if the picture impairment was to be rendered imperceptible.* However, it was not clear whether this performance would be adequate in the case of standards conversion, during which the spurious signals fluctuate regularly with time. Further, it was not clear whether there was any preference for a.m. or f.m. as a modulation system from the point of view of spurious signals.

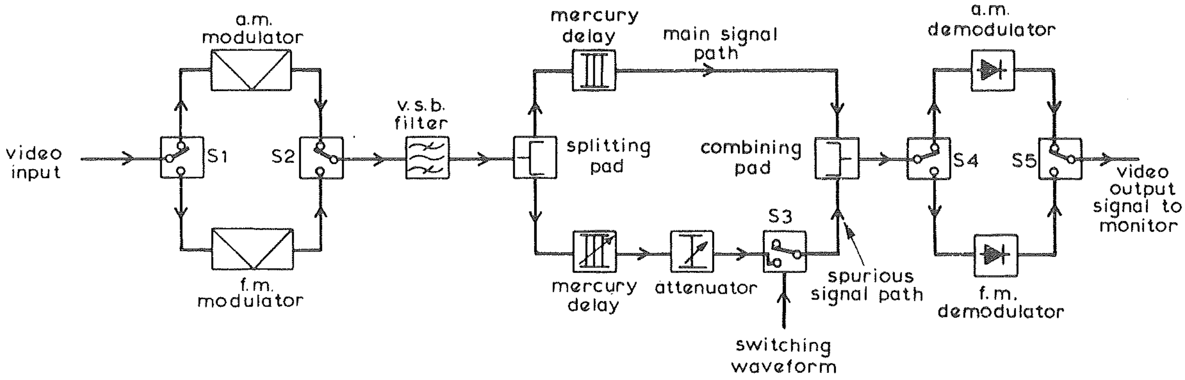
3. SIMULATION APPARATUS

In order to assess the effect of spurious signals using a.m. and f.m. transmission systems, the conditions of switching which will occur in a field-store standards converter must be simulated. It was therefore necessary to arrange for the presence of a spurious signal that could be switched on and off according to the sequences used in a field-store converter.

Although the switching sequences used for the various delays of a conversion system differ from one another, it has been found[4] that the visibility of the interfering patterns does not vary appreciably for the various switching sequences. It was therefore decided to simulate only the effect of a spurious signal generated in the ultrasonic unit of delay T since this would be sufficiently representative of any of the switching sequences.

Fig. 1 is a diagram of the simulation apparatus used for the investigation. It will be seen that two modulators were used, one providing an a.m. signal and the other an f.m. signal. The presence of a spurious signal was simulated using two variable ultrasonic mercury-delays, one of which carried the main signal and the other the spurious signal, which was switched on and off by an electronic switch. An attenuator was provided in the echo-signal path so that the relative levels of the main and spurious signals could be varied. By varying the value of the second delay any time separation between the main and spurious signals from 0 up to 250 μs could be achieved.

Experience has shown that the long fused-quartz delays required for the main store of a field-store converter will have a bandwidth of about 7



S1, S2, S4, S5 : manual switches
S3 : electronically controlled switch

Fig. 1 - Simulation apparatus

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* In this connection, it is of interest to note that, at present, a level of spurious signals of -40 dB may not be realised in the quartz blocks required for some of the long delays.

Mc/s. This bandwidth does not permit the use of double-sideband transmission in a field-store converter suitable for the American 525/60 and British 625/50 standards; for such a converter the minimum double-sideband bandwidth required would be twice the video-frequency bandwidth of the American system, namely 8·4 Mc/s. It was therefore essential that both the amplitude- and frequency-modulated signals be transmitted as vestigial-sideband signals. For convenience, the tests were carried out using a 625-line, 50-field signal. The a.m. and f.m. transmission systems are described in detail in another report[5] but their parameters may be summarised as follows:

Bandwidth of transmitted sideband:	5·5 Mc/s (to 3 dB point).
Bandwidth of vestigial sideband:	2·0 Mc/s
Upper and lower limits of band:	19 and 12 Mc/s
Carrier frequency:	17 Mc/s
F.M. deviation:	2·0 Mc/s. (Carrier frequency corresponding to black, 18 Mc/s; carrier frequency corresponding to white, 16 Mc/s).

4. EXPERIMENTAL INVESTIGATIONS

4.1. Picture Impairment due to a Spurious Signal : Amplitude Modulation

If present continuously, the spurious signal appears as a weak second image essentially similar to the main image and the carrier level of the output is different from that obtained in the absence of the signal; the change is, however, constant and may be readily compensated. If the spurious signal is switched on and off as a result of inserting and removing delays in a field-store converter, the carrier level is changed cyclically, due to the presence of the spurious signal. Thus the switching sequence causes a pattern of alternate light and dark horizontal bands to appear in the output picture together with a spurious image which is present during certain lines and absent on others. As a result, the visibility of the picture impairment due to the presence of a spurious signal is greater than that experienced when the spurious signal is present continuously.

It is possible to reduce the visibility of the interference in an a.m. transmission system by arranging that the carrier phases of the main signal and spurious signal are in quadrature. It is thought, however, that this technique would not be practicable in a field-store converter since it would probably be necessary to use a different carrier frequency for each delay producing a significant spurious signal; thus as many as twelve different carrier frequencies might be required. The tests were therefore conducted with the carrier phase of the spurious signal set at such a value as to produce maximum interference since this would correspond to the worst case met in practice.

4.2. Picture Impairment due to a Spurious Signal : Frequency Modulation

When the main signal corresponds to a large plain area of a certain brightness and the spurious signal corresponds to a large plain area of different brightness, elsewhere in the picture, the use of frequency modulation causes a sinusoidal variation of brightness to be superimposed on that region of the picture where the main and spurious signals overlap. The amplitude and frequency of this superimposed pattern are each proportional to the difference in brightness between the two areas. The presence of a spurious signal causes these sinusoidal variations of brightness to appear on much of the picture and tests show that, for a stationary scene, the pattern appears stationary and coherent from line to line; however, for a moving scene, the interference pattern appears to change rapidly in amplitude and periodicity.

Unlike the effect of a spurious signal when using an a.m. transmission system as discussed in Section 4.1, the change of carrier level that occurs in sympathy with the switching sequence is not reproduced and it is found that the visibility of the interference is slightly reduced instead of being increased.

4.3. Subjective Assessment of the Picture Impairment Caused by Spurious Signals

Subjective experiments were carried out to assess the visibility of the picture impairments due to a spurious signal for both a.m. and f.m. using a range of spurious signal amplitudes between -30 dB and -45 dB relative to the wanted signal. Two sets of tests were carried out in which one spurious signal was delayed either by 2 μs or by 10 μs relative to the main signal; these two values of delays were considered to represent the extremes likely to be encountered in the fused-quartz delays that would be used in a practical field-store converter.

The picture source used for the tests was a slide scanner and Test Card "C" was used as the test picture. Fixed viewing conditions* were maintained throughout the tests. Five skilled observers were first shown the interference due to a spurious signal of high level (-25 dB) and were then asked to assess the perceptibility of the interference due to the spurious signal at different levels using the following subjective impairment scale:

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* The observers sat at a distance five times picture height from the screen of the picture monitor. The intensity of "white" on the picture monitor was 25 ft-Lamberts (270 apostilb) and the ambient lighting intensity (measured on a white card) was 0·5 ft-Lamberts metric (5 apostilb).

1. Imperceptible
2. Just perceptible
3. Definitely perceptible but not disturbing
4. Somewhat objectionable
5. Definitely objectionable
6. Unusable

5. TEST RESULTS

The results of the subjective tests are shown in Table 1 below, where each figure is the mean of the opinions given by the five observers; it was found that the agreement among the observers was good and that the standard deviation did not exceed 0·3 subjective grades.

Table 1
Mean Subjective Grade

ATTENUATION OF SPURIOUS ECHO RELATIVE TO MAIN SIGNAL (dB)	2 μs SEPARATION		10 μs SEPARATION	
	a.m.	f.m.	a.m.	f.m.
30	5·4	2·6	5·2	2·8
34	5·0	1·4	4·6	1·4
38	3·8	1·0	4·0	1·2
42	2·2	1·0	2·2	1·0
46	1·2	1·0	1·2	1·0

6. DISCUSSION OF RESULTS

From Table 1 it may be inferred that, for a stationary scene, a single spurious signal would be imperceptible to 50% of people (grade 1·5) if the level of the spurious signal were 44 dB below the main signal when using a.m., and 34 dB below the main signal when using f.m. These figures cannot, however, be used directly in order to specify the permitted level of spurious signals in a fused-quartz delay, for two reasons:

(a) The field-store converter uses a number of delays and there would, in general, be more than one spurious signal present; in addition, each delay may exhibit several spurious signals, although it is likely that only the largest delays would be characterised by spurious signals of sufficiently high level to be annoying.

(b) For f.m., the random movement of the spurious pattern for a moving scene may increase its visibility, although this is not thought to have great significance.

Bearing these points in mind, it is thought that a reasonable specification for imperceptibility of spurious signals is -40 dB for an f.m. system and -50 dB for an a.m. system.

It is thus clear that f.m. has a distinct advantage over a.m. as a modulation system for use in the main store of a field-store converter. Further, it is unlikely that the figure of -50 dB required for a.m. could be met by the manufacturers of fused-quartz ultrasonic delays and for this reason the use of a.m. would result in the complication of additional circuits designed to compensate for the effects of the spurious signals.

7. CONCLUSIONS

The use of a frequency-modulated transmission system in the fused-quartz delays of a field-store standards converter is desirable since it will result in high gain-stability. The experiments described in this report show that, in addition, the use of frequency modulation will reduce the interference due to the presence of spurious signals in the fused-quartz delays. If amplitude modulation is used, the level of spurious signals in each fused-quartz delay will need to be at least 50 dB below the level of the main signal. However, if frequency modulation is used, the level of spurious signals can be 10 dB greater. Experience shows that the figure of 40 dB required for frequency modulation may, in the near future, be met in the design of fused-quartz delays, whereas the figure of 50 dB required for amplitude modulation is very unlikely to be met.

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